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COVER: A field of *Amitermes meridionalis* mounds (P. Jacklyn)

The Conservation Status of the White-throated Grasswren *Amytornis woodwardi*, an example of problems in Status Designation

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Abstract

The conservation status of the White-throated Grasswren has recently been designated secure, mostly on the basis of a recent survey which estimated its total population as about 50,000 to 60,000. This estimate is amended here to less than 10,000, and the process of changed fire regime may provide a substantial and continuing negative influence on this population. This case illustrates some more pervasive features complicating the designation of conservation status.

Introduction

Until a recent survey by Noske (1988), very little was known of the biology, distribution or population size of the White-throated Grasswren *Amytornis woodwardi* (Schodde & Mason 1975). Schodde (1982) noted that the species was restricted to the Arnhem Land sandstone plateau, but occurred there only in particularly suitable pockets and was "not widespread or very common anywhere". Collar & Andrew (1988) considered it "near-threatened", and Kennedy (1990) judged it "potentially vulnerable". Woinarski *et al.* (1989) included the White-throated Grasswren as one of a group of notable species in Stage III of Kakadu, a designation labelled "perplexing" by Holmes & Noske (1990).

In describing survey results which list several hundred species it is sensible to highlight some species which are most interesting, have special management requirements, or for which the area may have substantial conservation value. For managers of Stage III, and tourists who visit it, the White-throated Grass-wren is notable because (i) it is one of only two bird species restricted to the Northern Territory, (ii) the most popular and accessible spot to see the species is in Stage III, and indeed this location (UDP Falls, now renamed Gunlom) is widely recognised and recorded as such in guidebooks (e.g. Bransbury 1987), (iii) Kakadu National Park is one of only two conservation reserves in which the species occurs, and the population in the other reserve (Nitmiluk) is not very accessible, poorly known, and probably much smaller, (iv) a substantial proportion of the population occurs in Kakadu National Park, and specifically in Stage III, (v) the White-throated Grass-wren may be vulnerable to changes in fire regimes, and (vi) the total population size of this species may be small.

Instead, Noske (1988, 1990, 1992) and Holmes & Noske (1990) argue that this species is reasonably common, widespread and secure. Indeed, largely because of these claims, the status of this species was downgraded in the RAOU list of threatened birds of Australia to "species investigated but considered secure" (Brouwer & Garnett 1990). How can these disparate views be reconciled? Here I examine the results of Noske's (1988) reconnaissance survey (*sensu* Braithwaite 1985), and compare this with recent primary surveys of birds in the Kakadu area.

Assessment of Status from Reconnaissance Survey

In December 1987 and January 1988, Noske (1988) undertook an eight day field survey of White-throated Grasswrens aimed at searching for and censusing the species across its putative range. From this survey, he estimated the total population at between 30,000 and 100,000 birds, a range subsequently (Noske 1990, 1992) narrowed to "roughly between 50,000 and 60,000". This derivation was based on estimating densities in "suitable" habitat and then multiplying this density by the total area of that habitat. There are several caveats in this process, and how well these are considered will affect the reliability of the eventual total population estimate.

Counts and Population Density

White-throated Grasswrens are elusive and difficult to count in their rugged habitat. Noske's (1988) population survey involved brief visits, and his local population estimates are accordingly not derived from the usual census procedures of transects, quadrat counts or mark/recapture. The total counted was 46 birds spread over eight sites, a limited base from which to project entire population totals.

Noske (1988) gave a figure for the area of eight sites in which he recorded Grasswrens, although he didn't define how this area was measured. The density estimates for these sites are very variable (coefficient of variation = 122), which would limit the precision of any population projection. Average density was calculated by summing the total number of birds recorded and dividing this by the total area in which they occurred (in the process losing any possibility of assigning confidence limits to his estimates). Sites in which no birds were recorded despite searching in apparently suitable habitat (e.g. Diamond Creek) were excluded from this density calculation. This omission serves to inflate the population density estimate, by a factor which it is not possible to determine from the present data.

Suitable Range

Based on observations from the 11 known locations for this species, Noske (1988, 1992) considered that habitat suitability for this species is determined by vegetation characteristics (presence of spinifex) and topographic features (flat unbroken plateaus). He estimated the area of such suitable habitat from 1:100,000 topographic maps, as being 14,000 km². For most of this region, vegetation maps were not available at the time, so that one of the two key criteria of habitat suitability was apparently not considered in this estimate.

A check on the reliability of this estimate of extent of "suitable" habitat is available for Kakadu National Park, where a detailed habitat map (Schodde *et al.* 1987) portrays the distribution of sandstone spinifex. Noske (1988) estimated that about a quarter of the total Grasswren population occurs in Kakadu NP (implying that the area of suitable habitat there is 3,500 km²). In fact, the Schodde habitat map shows that only 660 km² of sandstone spinifex occurs in all of Kakadu (J. Tranter, ANPWS *pers. comm.*): that is, for the only area in which Noske's (1988) habitat prediction can be accurately assessed, that amount of "suitable" area is overestimated by a factor of more than five. But this area of sandstone spinifex may overestimate the extent of "suitable" habitat. Fire may render areas at least temporarily uninhabitable and may cause the elimination of some local populations. This means that much of the sandstone spinifex area may, at least temporarily, be unsuitable habitat for Grasswrens at any given time, and should not be included in the derivation of total population estimates. The very fragmented nature of the habitat (Woinarski & Braithwaite 1991) may also mean that many of the small and isolated patches may also be unlikely to hold Grasswrens.

Threats and population changes

There were no published population estimates or censuses prior to Noske's (1988) work, which makes any change in status difficult to detect. Both of the best known colonies appear to have declined during the last decade. At East Alligator, Ian Morris (in Noske 1988) reported "a dense population" of Grasswrens on several ridges and surrounding rocky outcrops in the 1970's. Noske located only three birds in this area in his detailed search in 1987. At UDP Falls (now renamed Gunlom), two of three Grasswren territories were severely burnt in 1987, with the results of eliminating their habitat there and consequent loss of birds.

Noske's (1988) data indicate some effects of fire. Of all his sites, two had been recently burnt by moderate intensity fires, whereas six had not been subject to recent (<1 year) burns. In the burnt sites, Grasswren density was 0.018 birds/ha (*s.d.* = 0.002); for the unburnt sites density averaged 0.085 birds/ha (*s.d.* = 0.086). Fire regime would appear to be an important factor in the ecology and survival of this species, as it is for other Grasswren species elsewhere (e.g. McKean & Martin 1989). Recent research is suggesting that the fire regime imposed upon the Arnhem Land massif is undergoing a marked and rapid change, with a decrease in small cool fires, and an increasing frequency of extensive very hot fires (Bowman *et. al.* 1990; Bowman 1991; J. Russell-Smith *pers. comm.*). The resulting change in the scale of the mosaic would be expected to have profound consequences for all species of this habitat.

Refining the population estimates

Considering the above qualifications, Noske's counts suggest an estimate of total population of well less than 10,000 birds.

Another Approach: Quadrat Data from Kakadu

Recently we have completed a two year wildlife survey of Stage III of Kakadu National Park (c 6,700 km²), which includes much of the southwestern extent of the

Grasswren's range (Woinarski & Braithwaite 1991). This survey was not intended to provide a population estimate of any particular species, and more intensive such work in sandstone habitats would be required for a confident estimate of overall numbers of Grasswrens. However, the data do provide some assessment of abundance and distribution, and provide a rough check on Noske's (1988) estimate and the amended estimate provided above. Over this period, 370 1 ha marked quadrats, spread representatively over habitats and geographic areas, were sampled. For all of these quadrats, birds were censused in 10 instantaneous counts per quadrat, spaced over four days. White-throated Grasswrens were present in only one habitat, Sandstone Spinifex, of the 22 habitats present and sampled. Their mean density in this habitat was 0.04 birds/ha, clearly not a common bird even in this preferred habitat. Woinarski *et. al.* (1989b) also censused sandstone spinifex in five quadrats in Stage I of Kakadu, without recording Grasswrens. Combined, these results provide an estimated population density of 0.027 birds/ha, and hence a population estimate for Kakadu of 1781 birds. Accepting Noske's figure that Kakadu probably holds about one quarter of the entire population, this gives a total population estimate of 7,125 birds (with very broad 95% confidence limits of 0 to 20,749). This estimate excludes any consideration of habitat made temporarily unsuitable due to recent fire, so is probably an overestimate.

Conclusions

This case has intrinsic interest and real conservation management implications. It also provides an example for more general problems. Firstly, it shows that those judging conservation status for Top End animals unfortunately are forced to base that judgement on a remarkable dearth of detailed biological information. Secondly, it demonstrates the desirability of using standard and acceptable census procedures, the need to include measures of error or variability in population counts and projections, the danger of predicting total population levels from limited base line data, and the importance of recognising qualifications in the interpretation of these projections. Thirdly, it illustrates the limitations of the pigeon-holes of status assignation. It remains unclear whether a population of 5000 to 10,000 renders the White-throated Grasswren secure or insecure, though this population level is obviously more exposed than one of 50,000 to 60,000, especially given the possibility of vulnerability to changing fire regimes. Finally, it concerns the question of how prudent we should be in defining status. If there is some doubt about population numbers and extent of threats, this uncertainty should be explicitly recognised, and the case investigated further. The presumption of security in such unclear cases is not prudent.

Acknowledgements

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Do Grasswrens have the numbers? Reply to Woinarski (1992)

In attempting to reconcile the disparate views about the status of the White-throated Grasswren *Amytornis woodwardi*, Woinarski (1992) has presented a somewhat tendentious argument. Collar & Andrew (1988) and Kennedy (1990) may have considered the species "near-threatened" or "potentially vulnerable", but neither have studied the species, nor evidently examined my report; indeed their assessments were based on the advice of other biologists. The labelling of the species as "notable" by Woinarski *et. al.* (1989) was considered "perplexing" by Holmes & Noske (1990) because: (a) the work of Noske (1988) was cited, but its conclusions ignored; and (b) the term "notable" had the distinct connotation of rarity and / or endangered status (see Braithwaite & Woinarski (1990) and Woinarski & Braithwaite (1990)). It is noteworthy that three other species categorised as rare

or endangered by Braithwaite & Woinarski (1990) (on the basis of a draft list) were also "downgraded" by Brouwer & Garnet (1990).

As Woinarski states, the methodology I adopted for censusing Grasswrens differed from that of ordinary surveys. I believe this method (active searching) was appropriate, however, given (a) the budgetary constraints (over which I had no control); and (b) the nature of the species. Instantaneous (quadrat) counts, as advocated by Woinarski, would have been a singularly inappropriate method for locating Grasswrens, which are masters of the art of being invisible. Due to its cryptic behaviour, this species is notoriously difficult to locate, even within known territories. Their songs are rather feeble and difficult to detect, and their contact calls are given mainly in response to disturbance. Such birds are likely to be under-counted using instantaneous quadrats, resulting in many zero scores, and yielding little information for time invested. It is no coincidence that three other members of this genus "disappeared" from the world for six or more decades, only to be reincarnated after a proper search.

After searching an area for Grasswrens, G. Holmes and I estimated the areas covered from 1: 100,000 topographic maps. The areal values did include patches of unsuitable habitats (vine forests and eucalypt woodland without rocks). Woinarski correctly states that I excluded sites where no Grasswrens were found (e.g. Diamond Creek) from my population densities: nor were they included in the area of suitable habitat used in the calculation of total population densities. It would be inappropriate to include densities for sites that were considered unsuitable habitat.

Woinarski uses the vegetation map of Schodde *et al.* (1987) to show that I overestimated the amount of suitable habitat in Kakadu, "by a factor of five". Based on my assumption that one-quarter of the suitable habitat (and one quarter of the grasswrens) were in Kakadu, he uses his own estimates of Grasswren density to derive a total population estimate of only 7,125 birds. The accuracy of this population estimate cannot be tested without additional data, but its credibility can be assessed by examining some of the attendant premises.

- (a) one quarter of the habitat is in Kakadu NP. The map from the recently produced Vegetation Survey of the NT map (Wilson *et al.* 1990) provides a convenient check on the viability of this premise. Using a planimeter, I estimate the area of suitable habitat (represented by Mapping Unit 32) within the known range of the Grasswren as 10,550 km². About 1,320 km² of this area occurs within Kakadu. This represents c. 12.5%, indicating that I over-estimated the amount of suitable habitat in Kakadu by a factor of two. Unfortunately, this estimate is also twice the area cited by Woinarski (based on Schodde's map). However, assuming that the proportion of habitat within Kakadu is 12.5%, and using Woinarski's Grasswren density estimate of 0.027 birds/ ha, the total population size should be about 14,000 - not less than 10,000 as Woinarski contends.
- (b) one-quarter of the habitat equates with one-quarter of the population. This assumption (made by both Woinarski and me) is fraught with difficulty, as the

density of birds can be expected to vary geographically with the amount of optimum habitat (elevated, flat plateaux: Noske 1988) and degree of fire protection. For example, about one-half of the suitable habitat in Kakadu lies some distance west of the main Arnhem sandstone plateau. Such isolated sites may be expected to have sub-populations with low Grasswren densities (on average), due to generally greater exposure to fire, and a smaller pool of potential colonists from which to recruit more birds. Lower average densities in Kakadu would tend to deflate, rather than inflate, our extrapolated total population estimates.

I find the claim that areas made temporarily uninhabitable by fire should not be included in derivations of population estimates difficult to accomodate. Any estimate of total population size is contingent upon the vagaries of natural or anthropogenic disasters affecting some or all of the species' sub-populations. Such estimates are merely a "snap-shot" of abundance, based on densities over a range of sites at a particular time. We intentionally visited sites with differing degrees of fire damage, including recently-burnt sites, to take such effects into account.

Woinarski contends that fire is a major threat to the species, citing the Carpentarian Grasswren as an example of another fire-threatened species. The analogy is imperfect, however, because the latter species occurs in disjunct populations, inhabiting relatively small outcrops with little fire protection, compared to the heavily dissected terrain occupied by the White-throated Grasswren (see also Schodde 1982). Woinarski has attempted to show that fire will adversely affect Grasswrens by comparing the densities at my recently-burnt sites with those of past-burnt sites. This comparison ignores the fact that most sites had apparently been burnt at some time over the last few years. Indeed I was impressed by the ability of Grasswrens to survive in areas of recent severe fires. Lower bird densities in such areas may be a short-term (temporary) phenomenon. Paradoxically, Grasswrens sub-populations might suffer longer term damage as a result of lack of fire (Noske 1988, 1992). Fire *may* have contributed to the decline of the East Alligator ("Cyril Springs" in Noske 1992) sub-population. Other factors include over-exploitation by a known (past) egg-collector, and a probable slow population recovery rate due to its peripheral, isolated location.

I appreciate the need to be prudent in designating the status of little-known species. I also accept Woinarski's criticism of my population calculations. However, I am still confident that the White-throated Grasswren is reasonably secure, with a total population size in excess of 10,000. As I look through the list of threatened bird species for Australia, I am struck by one profound fact: there has been only one avian extinction on the Australian mainland in the last two centuries (Brouwer & Garnett 1990; Garnett 1992). This situation contrasts sharply with that for the Australian terrestrial mammals, which have suffered more than any other continental mammal fauna in historical times. This is not to say that concern about the conservation of birds is unwarranted, but as biologists, we need to recognise that

the economic realities of conservation demand that those species or communities most sensitive to disturbance, and/ or at greatest risk of extinction, are given priority over less convincing cases.

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Solar Engineering for the Blind: "Magnetic" Termite Mounds of the Top End

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Abstract

The termites *Amitermes meridionalis* and *A. laurensis* construct meridional mounds across northern Australia which vary geographically in mean orientation from 11° E to 15° W in a manner that suggests such variation is an adaptive response to local environmental conditions. Theoretical modelling of solar irradiance, mound rotation experiments and analysis of weather conditions show that maintenance of an eastern face temperature during the dry season explains the variation in mound orientation. This is affected by wind speed and shading conditions. Further study of the spatial and temporal distribution of mound orientations, together with experiments on mound growth in magnetic fields, indicates that the mounds are constructed along inherited magnetic cues and that natural selection matches mean mound orientations to environmental conditions.

Introduction

The most famous architects of the Top End region of the Northern Territory are a few millimeters long and blind. The spectacular tombstone-shaped "magnetic ant-hills" in this region are constructed by the worker caste of the termite *Amitermes meridionalis* (Froggatt). Termites are social insects, related to cockroaches, not ants. Their diet is based on cellulose. Colonies of *A. meridionalis* collect plant litter using subterranean galleries radiating from the mound. This material is then stored in the outer galleries of the mound and used to feed the colony. The mounds are constructed on the edges of seasonally flooded alluvial flats extending from Koolpinja in the north to the Daly River in the south. Mature mounds are large flat plates, around 2 m high, which taper from a massive base to a turreted ridge that is oriented along a north-south axis (Cover Plate). Thus each mound is approximately aligned with a meridian of longitude, giving the specific name *meridionalis*.

The mounds are remarkable in a number of ways. First, although they may be a familiar feature of the bush to Top End residents, in the context of termite mounds world-wide, they are spectacular oddities. Termite mounds are found throughout the tropics and are generally conical, cylindrical or dome-shaped. Clustered, plate-shaped mounds aligned in the same direction, occur only in northern Australia. Such meridional mounds are built by at least three termite species in northern Australia: *A. meridionalis*, *A. laurensis* (Mjoberg) and *A. vittiosus* (Hill). The last species does not commonly build meridional mounds and was not included in this study.

The precise shape of these mounds is a key to explaining their function. Because the mounds are always constructed in seasonally flooded areas, their shape is probably adapted to these habitats. Various explanations for the adaptive value of meridional mounds have been advanced (Jacklyn 1991), but none of them satisfactorily explain the geographic variation in mound orientation described below.

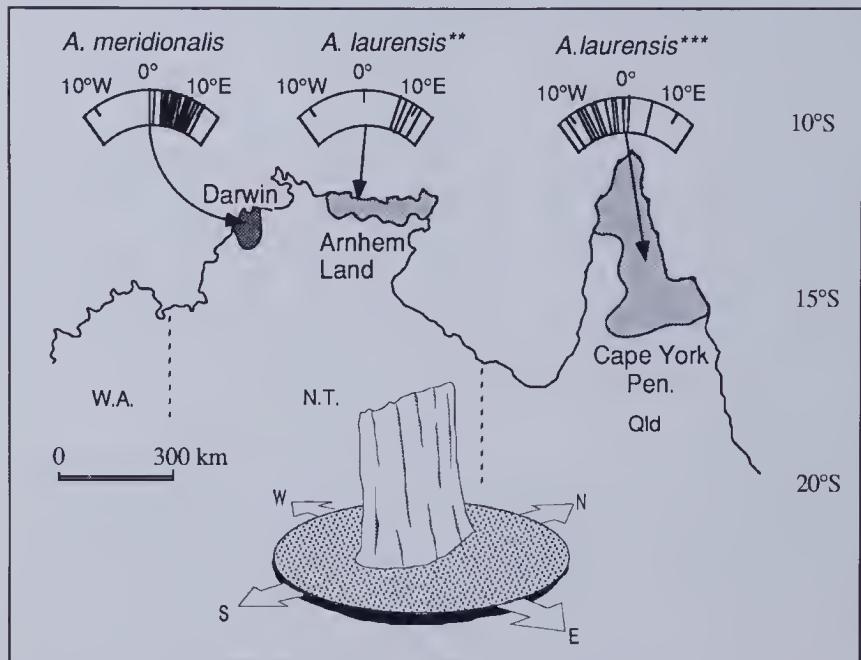


FIGURE 1 The distribution of meridional mounds and the variation in mean mound orientation of 47 *A. meridionalis* sites near Darwin, 4 *A. laurensis* sites in Arnhem Land and 17 *A. laurensis* sites in Cape York Peninsula. Each angular line represents the mean geographic orientation of 20 - 50 mounds (note: several sites have the same mean orientation). **, Grigg & Underwood (1977); ***, 13 sites from A. Spain (unpubl. data); all other sites surveyed by the author.

Variation in Mound Orientation: a model

Measurement of the orientation of a large number of *A. meridionalis* mounds makes it clear that these mounds are not like compass needles, all oriented to magnetic north, nor are they strictly meridional, all oriented to geographic north. Rather, mound populations vary in mean orientation from 0° (geographic north) near the coast at Mandorah, to 10° E (geographic) in the south of Litchfield Park. Similarly, populations of 'meridional' *A. laurensis* mounds in Cape York Peninsula and

Arnhem Land vary in mean orientation from 10° E in Arnhem Land to 15°W in Cape York (Fig. 1; Grigg & Underwood 1977; Duelli & Duelli-Klein 1978; Spain *et al.* 1983; Jacklyn 1991). This variation follows the broad environmental gradient between inland and coastal regions around Darwin, and between the Top End and Cape York Peninsula across northern Australia.

A possible explanation for this pattern is that the mounds are conserving some physical property that is important for termite survival, and is dependent on both the mound orientation and environmental conditions. Thus, maintaining such a property is a matter of adjusting mound orientation to suit local environmental conditions, and, as these conditions change, the optimum mound orientation also changes. But what mound property could be sensitive to such small changes in mound orientation as well as being sensitive to environmental conditions? One way of finding out is to rotate meridional mounds through the small differences in orientation seen between populations and see what physical properties are consistently changed. When this is done an intriguing phenomenon emerges: the mounds seem to be oriented so that they maintain a temperature plateau on the eastern face of the mound during dry-season days. In other words, unlike almost any other organism in the world, they create a thermostable surface on one side of a large plate.

This temperature plateau is sensitive to two factors:

The orientation of the mound and the time of year.

During the dry season when the sun describes an arc across the northern sky, the pattern of solar irradiance on each face is critically dependent on mound orientation. Mounds oriented more to the *northwest* receive more radiation on their *eastern* faces: this face is heated above air temperature by the middle of the day, and tends to cool down in the afternoon. Mounds oriented more to the *northeast*, on the other hand, receive more radiation on their *western* faces, and the cooler *eastern* face tends to warm in the afternoon (Fig. 2).

Wind and shade conditions

South-easterly trade winds blowing on the eastern face of the mound during the dry season will lower face temperatures in the morning when air temperatures are low. Thus, for mounds to maintain optimum eastern face temperatures in areas exposed to the dry season winds, they will have to be oriented more to the west than more sheltered mounds, so that the east face collects more radiant heat to offset the wind effect.

Similar arguments show that mounds in shaded habitats with shadows (from either trees or clouds) passing across their eastern faces should also be oriented more to the west. Because habitats shaded by vegetation contain a range of shade micro-habitats from unshaded to completely shaded, one would expect a random sample of mounds from such habitats to have a greater variance in orientations than a sample of mounds from nearby open habitats. According to this model of mound orientation, the observed variation in mean mound orientation across northern

Australia is caused by the geographical variation in long-term wind and shade conditions.

Testing the Model

If the above model is correct, i.e. the mounds are conserving a dry season eastern face temperature plateau, it should be possible to predict the expected variation in mean orientation of meridional mounds across northern Australia by referring to long-term wind speed and cloud cover records. Sure enough, these predictions match the observed variation in mound orientation: the mounds on the coast near Mandorah are a few degrees west of mounds in Litchfield Park as one would expect given the higher coastal winds during the dry season; mounds in shaded habitats are more variable in orientation than mounds in nearby open habitats; the *A. laurensis* mounds in Cape York Peninsula are oriented well to the west of mounds in the Top End (Fig. 1) because they experience the high winds and cloud cover associated with the passage of easterly trade winds sweeping in off the Pacific Ocean during the dry season (by the time these winds reach the Northern Territory they are weaker and drier).

How 'Magnetic' Termites Construct their Mounds

If the feat of small, blind insects constructing a massive plate a thousand times higher than themselves is enough to boggle the mind, then the ability of the same insects to orient this plate so that it matches long-term dry season wind speed and cloud cover conditions is quite incredible. This incredulity is strengthened by the observation that most mound construction occurs during the wet season - the time of year when these climatic cues are absent.

Not unexpectedly perhaps, observation of mound growth and the distribution of mound orientation suggest that mounds are constructed along a fixed axis. That variation in mound orientation within populations decreases with age further suggests that mound orientation is matched in environmental conditions by natural selection: mounds built along genetically fixed axes appropriate to the local climatic conditions grow to maturity and make a contribution to the next generation of mounds; mounds built along inappropriate axes do not reach maturity and the genes for that axis are weeded out of the population gene pool. This orientation mechanism makes the mounds vulnerable to rapid changes in climate - cause for concern, given predictions for the effects of increasing concentrations of atmospheric greenhouse gases on the earth's climate.

In the light of these investigations, the name 'magnetic' mound may seem inappropriate, but when one considers the ways in which a genetically inherited directional cue might be used by termites, the use of magnetic cues seems an obvious possibility. Therefore, I investigated the effect of changes in the direction of the surrounding magnetic field on mound growth. Although these experiments could only be carried out on mound repair (the axial extension of the mound that occurs in normal growth takes many years), the internal structure of the repaired

part of the mound was aligned with the magnetic field in a manner consistent with the use of magnetic declination to orient the mound. This is not to say that the termites align the mound with magnetic north, but that they align it along an inherited magnetic axis with a bearing that is likely to be appropriate to the long-term wind speed and shading conditions of the habitat (assuming the colony was founded by alates from a nearby mature mound).

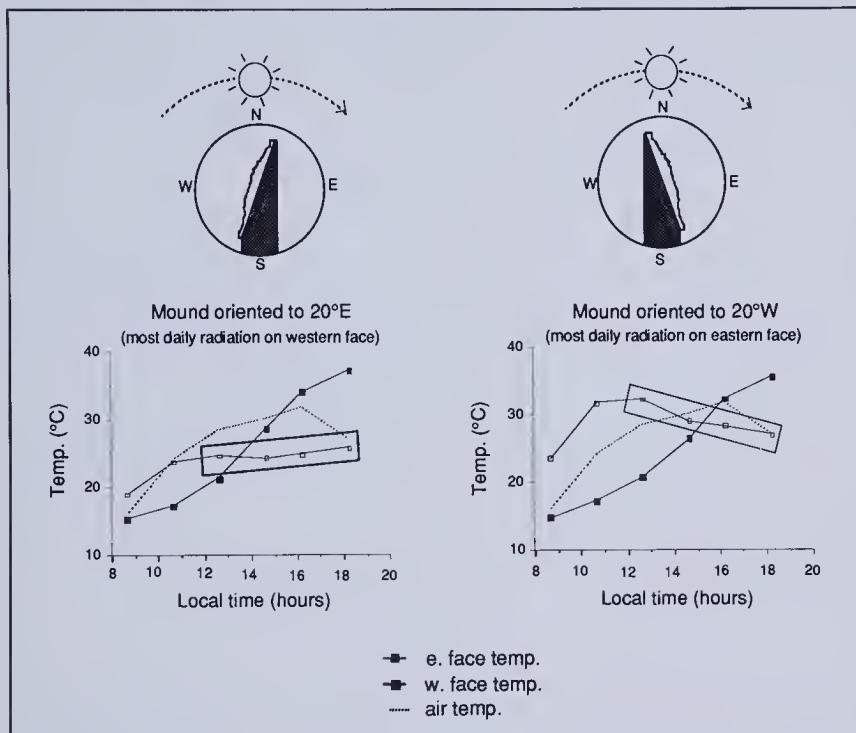


FIGURE 2 The effect of mound orientation on eastern face cooling (boxed areas). Plan view of mounds shown above each temperature graph.

This suggestion raises as many questions as it answers. How do termites detect magnetic cues? (Other insects have been found to have magnetic receptors: Becker 1963; Becker & Speck 1964; Martin & Lindauer 1977). What is involved in inheriting a colony trait like mound orientation, which is the product of the combined behaviours of many termites, each with their own slightly different genetics? (see Dawkins 1982, for an interesting discussion on this point, featuring none other than 'magnetic' termite mounds). What happens when the magnetic field changes direction over time? The earth's magnetic field has its origin in the electrically

conductive molten iron that surrounds the earth's core; consequently it is not fixed in direction but varies slowly over time. This secular variation has been tracked ever since sailors first used compasses, and in most parts of the world, the direction of the magnetic field changes by a few degrees every century. This should pose problems for long-lived termite colonies (old colonies may live for over 100 years) which depend on the magnetic field to provide a directional cue that is sufficiently stable to be a useful guide to a precise geographic orientation over many generations of mounds. Interestingly, however, the geomagnetic field direction over northern Australia is unusually stable, hardly varying at all over the last few hundred years for which records are available. It could be that one of the reasons why northern Australia (and possibly New Guinea) has at least three or four different kinds of meridional termite mounds (whereas the rest of the tropics have none), is the stability of the magnetic field in the northern Australian region.

Why should these termites have evolved such an awkwardly sensitive method of temperature control? The key to seeing the advantages of such an adaptation lies in the nature of seasonally flooded habitats. During the wet season these depressions offer advantages and disadvantages to plant litter feeding termites: the water-logging produces abundant stands of the spear grass *Sorghum intrans* which are a source of nutrition for termites; the same water-logging also destroys any underground refuges of the termites, and they are trapped in the mound above ground. During the dry season these areas are moist enough (perhaps through the dew-fall associated with nocturnal cool air drainage) to support plenty of annual grasses that provide more food for the termites; however, the vagaries of cool air drainage also give these habitats great variation in air temperature and humidity during the dry season.

Other species of termites cope with a variable environment by building mounds with a complex internal architecture that creates a stable internal environment (e.g. see Lüscher 1961), or by moving underground (Bouillon 1970). These options are not available to *Amiatermes* in seasonally flooded habitats: complex mound architecture is not seen in this genus and any underground refuges are destroyed by water-logging that can persist into the early dry season. One way of making a simple mound shape thermo-stable is to make it massive. Another, more efficient solution is to construct it as a surface, the thermostability of which is determined by its orientation to the sun and the wind and shading conditions. The more flat and elongated the mound is, the more living space is incorporated into the thermostable regions of the mound.

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Further Interesting Bird Records from the Gulf of Carpenteria and Arnhem Land

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Introduction

The Gulf of Carpenteria region has a comparatively long ornithological history, with a number of collectors working in the region of Borroloola (Hill 1913; Barnard 1914a), the Roper River mouth (Bennett 1983) and the Barkly Tablelands (Ingram 1907; Barnard 1914b) early this century. More recently, biological survey work has been undertaken near Borroloola by the CSIRO Division of Wildlife Research (Schodde 1976), and throughout the region from 1976 to 1981 by the Royal Australasian Ornithologists Union, as part of the Australia-wide Atlas of birds (Blakers *et al.* 1984).

Arnhem Land's ornithological history began even earlier; notably with John Gilbert's work near Port Essington in 1841 (Campbell 1919). Collecting and observing trips subsequently have been made to the Arnhem Land region by Baldwin Spencer in 1912 (Whittell 1954); William McLennan in 1915-16 (White 1917); Norman Tindale in 1921-22 (Tindale 1925a, 1925b); the American-Australian Scientific Expedition in 1948 (Deignan 1964); CSIRO in 1961 (Frith & Hitchcock 1974); the Harold Hall Expedition of 1968 (Hall 1974); and the RAOU (Bennett 1983; Blakers *et al.* 1984).

Notwithstanding these bird collecting and bird observing surveys, the distribution and dispersal of birds in the Gulf of Carpenteria and Arnhem Land regions remains poorly known. For example, a recent paper by Holmes and Noske (1990) documented range extensions for 17 species of bird in those two regions, and reported one species, Spinifexbird *Eremiornis carteri*, not previously known from the Gulf.

Here we report some further extensions of range, or records of interest, for 20 bird species recorded in the Gulf or Arnhem Land regions during surveys conducted by the Conservation Commission of the Northern Territory (CCNT), or incidentally by other observers. Observations were mostly made during the Gulf Region Fauna Survey (1984-1988), a CCNT fauna survey of monsoon vine forests in the Northern

Territory between April and September, 1990, or by John and Judy Whitaker while living at Borroloola. Some additional incidental observations held in the public database of the Biological Records Scheme (BRS) of the CCNT are also included. Nomenclature follows Blakers *et al.* (1984). Latitudes and longitudes of all locations are given in Appendix 1.

Annotated List of Species

LEAST FRIGATEBIRD *Fregata ariel*

- Borroloola, 1 bird, March 1985, picked up by John and Judy Whitaker following Cyclone Sandy.

Not recorded by Schodde (1976).

PACIFIC BAZA *Aviceda subcristata*

- Trig Hill, near Borroloola, 1 bird seen by John Whitaker, May 1984, over a small waterhole north of Trig Hill.
- Beetle Springs, McArthur River Station, 1 bird, 8-5-90, over *Melaleuca*-lined watercourse in sandstone escarpment.

Blakers *et al.* (1984) comment that few records of this species exist from the Gulf of Carpenteria region. Recorded only once by Schodde (1976); two birds along the McArthur River, May 1976.

RED-CHESTED BUTTON-QUAIL *Turnix pyrrhothorax*

- 100 km W. of Nhulunbuy, 3 birds, 29-7-90, in dense 0.5 m high grass in damp grassy flat beneath *Eucalyptus oligantha* woodland.
- 50 km S. of Ramingining, 2 birds, 4-8-90, in *E. miniata/tetrodonta* woodland with a 1 m high *Sorghum* spp. understorey. Restricted to unburnt grass patches; not observed in burnt patches. Groups of Chestnut-backed Button-quail *T. castanota* at the site were observed in recently burnt woodland without any grass cover and in nearby vine thickets; not recorded feeding in either of these cases.

Both records extend the eastern range of Red-chested Button-quail in Arnhem Land (Blakers *et al.* 1984) and supplement other dry season records from northwestern Australia (McKean 1985; Jaensch 1989; Woinarski 1990).

BAILLON'S CRAKE *Porzana pusilla*

- Little Fletcher Swamp, near Borroloola, 1 bird seen by John and Judy Whitaker, September 1985.

First known record for the region (Schodde 1976; Blakers *et al.* 1984).

DUSKY MOORHEN *Gallinula tenebrosa*

- Little River, near Cape Crawford, on Carpentaria Highway, 2 birds, August 1976, seen by Hilary Thompson.
- Calvert River, just below the Gulf Highway crossing, 1 bird, 29-9-86, along edge of permanent waterhole.

First known records for the Gulf region, although this species has been reported to be moving westwards in recent times (Blakers *et al.* 1984). More recently recorded from just south of Borroloola (16°37'S, 136°19'E), 12-4-88, and 10 km south-east of mouth of Calvert River (16°21'S, 137°46'E), 21-3-90 (BRS).



PLATE 1 Hooded Parrot at nest (J. Estbergs)

PAINTED SNIPE *Rostratula benghalensis*

- Bauhinia Downs station, 1 bird, 29-8-85, flushed several times by Gerry O'Neill and Mike Fleming from the edge of a small paperbark swamp located on top of a sandstone plateau.

First known record for Gulf region (BRS; Storr 1977; Blakers *et al.* 1984). Only previously published Top End record from Victoria River Downs (Boekel 1980).

INLAND DOTTEREL *Peltomyias australis*

- 7 km north of Borroloola, 1 bird, 28-5-85, seen by John Whitaker in wet grassland.
- 80 km N. of Barkly Homestead on Tablelands Highway (19°00'S, 136°00'E), 14 birds, 20-11-90, cracked clay plains with sparse tussock grass.

Northern extension of range (Storr 1977; Blakers *et al.* 1984). Not recorded on Barkly Tablelands by Ingram (1907), Hill (1913) or Barnard (1914a).

RED-NECKED AVOCET *Recurvirostra novaehollandiae*

- 5 km west of the mouth of Robinson River, a large flock of birds, 21-4-88, flushed from saline flats during an aerial survey.

First known record for the Gulf region (Storr 1977; Schodde 1976; Blakers *et al.* 1984), although its apparent absence may simply reflect the difficulties of access to the saline coastal flats. Recent sightings in the Queensland section of the Gulf (Claridge & Johnson 1988) would support this contention.

ROSE-CROWNED FRUIT-DOVE *Ptilinopus regina*

- Manangoora Station, 1 bird, December 1982. Seen by Brian Walsh (BRS).
- Bauhinia Station, 1 bird, 1-6-89, in closed forest adjacent to a large waterhole. Observed by Bill Lowe and Else Foster (BRS).
- East of Calvert River, Gulf of Carpenteria, 1 bird, 30-5-90, feeding in *Ficus virens* in coastal vine thicket.
- Annie Creek, south Arnhem Land, 1 bird, 13-7-90, in evergreen rainforest.

The first three records all extend the fruit-dove's known distribution in the NT; eastern limit previously considered to be Port Bradshaw ($12^{\circ}30'S$, $136^{\circ}40'E$) and Sir Edward Pellew group of Islands ($15^{\circ}35'S$, $136^{\circ}40'E$) (Schodde 1976; Storr 1977; Blakers *et al.* 1984). The latter record is at the edge of the species' distribution in the Arnhem Land interior (Blakers *et al.* 1984).

HOODED PARROT *Psephotus dissimilis*

- 50 km S. of Ramingining, northern Arnhem Land, 5 birds in one flock and occasional other pairs seen, 3-8-90. Habitat is open *Eucalyptus miniata*, *E. tetrodonta*, *E. bleeseri* woodland with *Sorghum* spp. understorey.

Although recorded from this region previously (Blakers *et al.* 1984), the vulnerable status of this species (Brouwer & Garnett 1990) warrants continued recording of its presence at known sites.

RUFOUS OWL *Ninox rufa*

- Echo Gorge, Wollogorang Station, 1 bird, 29-3-86, in sandstone jungle gorge off Echo Gorge.
- Annie Creek, 1 bird observed and heard, 13-7-90, in evergreen rainforest along the creek.
- 50 km S. of Ramingining, 1 flushed from vine thicket with tall canopy cover.

The Echo Gorge sighting is the first confirmed record for the Gulf region. Barnard (1914a) flushed what he considered to be a pair of Rufous Owls from along the Macarthur River, but was not certain. The latter two records help define the distribution of the species in Arnhem Land (Blakers *et al.* 1984; Holmes & Noske 1990).

MASKED OWL *Tyto novaehollandiae*

- 100 km W. of Nhulunbuy, eastern Arnhem Land, 1 bird, 22-7-90, heard calling from tall *Eucalyptus tetrodonta* forest along a ridge with sparse shrub understorey, scattered vine thickets on slopes. Calls later compared with tapes of Masked Owl and Barn Owl *T. alba* calls to corroborate identification.

There are few records of this species from northern Australia, although Arnhem Land may be a stronghold (Blakers *et al.* 1984). The status of this species is unclear (Blakers *et al.* 1984); Storr (1977) described it as scarce.

RAINBOW PITTA *Pitta iris*

- Annie Creek, 2 birds, 13-7-90, in evergreen rainforest along the creek.

Slight inland range extension within Arnhem Land.

VARIED TRILLER *Lalage leucomela*

- Broadmere Lagoon, 1 bird, 24-5-89, seen by Bill Lowe in eucalypt woodland adjacent to lagoon (BRS).

First confirmed record from the southern Gulf region (Blakers *et al.* 1984).

LITTLE SHRIKE-THRUSH *Colluricincla megarhyncha*

- Alligator Waterhole, Bauhinia Downs Station, 1 bird, 1-6-89, seen by Bill Lowe in patch of rainforest adjoining waterhole (BRS).
- Mouth of Calvert River, 2 birds, 5-6-87, in mangroves adjacent to tidal flats.
- Echo Gorge, Wollogorang Station, 1 bird, 22-9-86, at entrance to Banyan Gorge.

Based on habitat, the latter bird may belong to the Queensland subspecies *C. m. parvissima* (Ford 1979), rather than the lower McArthur River subspecies *C. m. aelpetes* (Schodde & Mason 1976; Ford 1979), providing a closer link between the eastern and western populations of this species. The coastal record extends the species' known distribution in the Northern Territory; previously considered to be the mouth of the Macarthur River (Schodde 1976; Schodde & Mason 1976).

MANGROVE GOLDEN WHISTLER *Pachycephala melanura*

- Mouth of Calvert River, 1 bird, 5-6-87, in low monsoon forest on a coastal dune.
- East of Calvert River, 1 female or young male, 31-5-90, in coastal vine thicket close to mangrove patch.

Extends known range of this species in the NT eastwards; eastern limits within NT previously given as the Lower McArthur River and Groote Eylandt (14°00'S, 136°40'E) (Storr 1977); the westernmost records from Qld are from the Burketown region (17°00'S, 139°30'E) (Blakers *et al.* 1984).

SHRIKE-TIT *Falcunculus frontatus*

- 50 km S. of Ramingining, 2 birds, 6.8.90, in *Eucalyptus miniata*, *E. tetrodonta*, *E. bleeseri* woodland with *Sorghum* spp. understorey. Observed feeding on bark of each of these three tree species, as well as the bark of one dead tree. Not heard calling, and not recorded on other days.

This record significantly extends the known range of the shrike-tit; previously known mostly from localities further south between Pine Creek and Larrimah (Storr 1977; Robinson & Woinarski 1992). Appears to comprise the 28th known record of this sub-species (Robinson & Woinarski 1992).

RUFOUS FANTAIL *Rhipidura rufifrons dryas*

- Blackfella Springs, 3 birds, 29-9-86, in dense stand of *Melaleuca* spp., and along edges of creek.
- Calvert River, just below Gulf Highway crossing, 1 bird, 29-9-86, in deep gully.

- Echo Gorge, Wollogorang Station, 1 bird, 23-9-86, in dense growth in Banyan Gorge.
- Mouth of Calvert River, 1 bird, 5-6-87, in low, coastal vine thicket.
- East of Calvert River, 1 bird, 31-5-90, in coastal vine thicket adjoining mangrove patch.

These records all extend the known distribution of this species along the coast and sub-coastal region of the Gulf of Carpenteria; eastern limits within NT previously given as the Lower McArthur River (Schodde 1976; Storr 1977); within Qld, the western limits were previously given as near Karumba ($17^{\circ}29'S$, $140^{\circ}50'E$; Blakers *et al.* 1984).



PLATE 2 Little Shrike-thrush at nest (J. Estbergs)

BLACK HONEYEATER *Certhionyx niger*

- Caranbirini Waterhole, 1 bird, 5-9-85, feeding on flowering *Melaleuca* spp.
- McDermott's Springs, Gulf of Carpenteria, 2 birds, 4-6-90, in woodland of flowering *Eucalyptus miniata*. Many (c. 50) Grey-fronted Honeyeaters *Lichenostomus plumulus* also present.

These records are at the northern edge of this species' distribution in the Gulf of Carpenteria (Blakers *et al.* 1984).

PIED HONEYEATER *Certhionyx variegatus*

- Benmara Station, many birds, 2-6-87, feeding on flowering *Grevillea pteridifolia* in heathland.

This represents only the second known record for this species in the Gulf region. One was seen previously by Joan Paton at Billengarah Station ($16^{\circ}18'S$, $135^{\circ}43'E$), 28-7-85, in open woodland (BRS).

Discussion

The records listed above include observations of five species previously unknown from the Gulf of Carpenteria region (Baillon's Crake, Dusky Moorhen, Painted Snipe, Varied Triller and Pied Honeyeater), and one species recorded only once previously (Red-necked Avocet). Also of interest was the record of the Shrike-tit from near Ramingining, a range extension of approximately 160 km and the first known record of this species from the Arnhem Land region (Robinson & Woinarski 1992). These records highlight the dearth of basic biological information for many bird species in northern Australia, and indicate how little we still know about their distributions and broad habitat needs.

The records also highlight how little we know of seasonal patterns of movement in northwestern Australia. For example, do Black and Pied Honeyeaters regularly move north in the winter to feed on flowering eucalypts and Grevilleas, or is it an irregular event? Do Pacific Bazas regularly visit the Gulf in winter, and if so, from where? Where do Red-chested Button-quails move to during the wet season? What are the origins of the Rose-crowned Fruit-doves, Mangrove Golden Whistlers, Little Shrike-thrushes and Rufous Fantails seen east of Calvert River and elsewhere in the Gulf: are they sedentary, or have they dispersed from along the coast, either from further east or further west?

The arid interior at the base of the Gulf of Carpenteria has long been recognised as an important zoogeographic barrier (Spencer 1896; Keast 1961), preventing dispersal between northwestern and northeastern populations of many tropical, rainforest and woodland species (Keast 1961; Ford 1982; Russell-Smith & Dunlop 1987). The records of Rose-crowned Fruit-dove, Little Shrike-thrush, Mangrove Golden Whistler and Rufous Fantail from east of the Macarthur River in the Gulf region suggest that individuals of some rainforest species may be able to disperse between the north-eastern and north-western rainforest refugia, and that some gene flow may occur along the coastal vine thicket fringe. Conversely, individuals of most other rainforest species restricted in Australia to the Top End, Kimberleys and eastern States (e.g. Orange-footed Scrubfowl *Megapodius reinwardt*, Rainbow Pitta, Varied Triller, Grey Whistler *Pachycephala simplex*, Dusky Honeyeater *Myzomela obscura* and Figbird *Sphecotheres viridis*) were absent from the Calvert River and McArthur River districts (this study; Schodde 1976), implying that the arid hinterland of the Gulf of Carpenteria does effectively prevent dispersal of many rainforest birds. The absence of these species from isolated patches of rainforest habitat in the Gulf region implies furthermore that rainforest-dependent birds may be vulnerable to habitat loss in northern Australia (see Smith & Johnstone 1977; Bennett 1983; Brooker *et al.* 1990), in part due to poor dispersal abilities across unsuitable habitats. This implication is significant in that most rainforest patches in the Northern Territory are small and isolated, many of them degraded or threatened by grazing and fire (Bennett 1983; Brooker *et al.* 1990; Russell-Smith & Bowman 1992).

It is symbolic of our knowledge of the avifauna in northwestern Australia that the most detailed accounts of many bird species' distributions, habitats and habits continue to be based on information collected last century and early this century

(e.g. Ingram 1907; Hill 1913; Barnard 1914a, 1914b; Mathews 1914; White 1917; Campbell 1919). However, the status of many bird species has changed since these early expeditions (Blakers *et al.* 1984), notably due to extensive habitat modification through grazing and fire (Blakers *et al.* 1984). Much more information is needed on species' current distributions, dispersal patterns and ecological needs in northwestern Australia. Only with that knowledge can we begin to make recommendations for bird species conservation.

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APPENDIX 1 Latitudes and longitudes of localities mentioned in text

Alligator Waterhole	(16°05'S, 135°22'E)	Echo Gorge, Wollogorang Station	(17°11'S, 137°41'E)
Annie Creek	(13°02'S, 134°56'E)	Little Fletcher Swamp	(16°01'S, 136°30'E)
Barkly Homestead, 80 km N.	(19°00'S, 136°00'E)	Macarthur River, mouth	(15°50'S, 136°40'E)
Bauhinia Downs stn.	(15°55'S, 135°09'E)	McDermott's Springs	(17°25'S, 137°48'E)
Beetle Springs	(16°47'S, 135°59'E)	Manangoora Station	(16°01'S, 136°51'E)
Benmara Station	(17°36'S, 136°51'E)	Nhulunbuy, 100 km W.	(12°36'S, 136°32'E)
Blackfella Springs	(17°19'S, 137°03'E)	Ramingining, 50 km S.	(12°38'S, 134°49'E)
Borroloola, 7 km N.	(16°06'S, 136°17'E)	Robinson R, 5 km W. of mouth	(16°02'S, 137°13'E)
Broadmere Lagoon	(16°26'S, 135°12'E)	Trig Hill	(16°02'S, 136°18'E)
Calvert R, East	(16°27'S, 137°53'E)		
Calvert R, mouth	(16°16'S, 137°43'E)		
Calvert R/ Gulf Hwy crossing	(16°55'S, 137°21'E)		
Cape Crawford	(16°39'S, 135°47'E)		
Caranbirini Waterhole	(16°16'S, 136°05'E)		

Preliminary Observations on the Northern Blossom-Bat *Macroglossus minimus* in Captivity

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Introduction

The Northern Blossom-bat *Macroglossus minimus* (Geoffroy, 1810) is a small, (head-body length, 59-64 mm; weight, 11-19 g) nectar and pollen feeding bat, found in northern Australia from the Kimberleys to northern Cape York. Its extralimital distribution includes New Guinea, the Bismarcks and the Solomon Islands (McKean 1983) and much of northern Indonesia. Originally described from Australia by Ogilby in 1892 as *M. australis*, the first specimen was collected from the Murray Islands in Torres Strait. Australian forms have since been placed in *M. minimus*, originally described from Java (Geoffroy 1810). Currently four subspecies are recognised, the sub-species occurring in Australia being *M. m. pygmaeus* Anderson (Anderson 1911).

M. m. pygmaeus is now considered a common species in the "Top End" of the Northern Territory, associated with monsoon forests, paperbark swamps, bamboo thickets, dense riverine vegetation and mangroves (Kitchener *et al.* 1981; Thomson 1991). By day, these bats appear to roost alone, although reported sightings are few. These include roosts in bamboo thickets and the rolled-up young leaves of bananas (McKean 1983). Outside Australia the bats have been found roosting alone, or in small groups under the canopies of large leafed trees and palms, and beneath roofs of uninhabited buildings (Flannery 1990).

Up to November 1991 a total of 13 *M. minimus* individuals have been kept at the Territory Wildlife Park, Berry Springs, Northern Territory. Six wild bats (3 males, 3 females) were caught during February 1988 and October 1989. They were trapped using Monofilament mistnets (mesh size c. 25 mm) in the early evening beside a paperbark swamp, and on the fringe of a monsoonal vine forest, within the Wildlife Park. After capture these bats were held temporarily at the Holding Block, before being moved to the Nocturnal House. Five individuals have been bred in captivity (4 males and 1 female). This paper, describing observations of these captive individuals from 1989 to 1990, represents the first account of the captive maintenance and breeding of this species.

Methods

Individual bats were marked for identification using size 04 alloy bat bands (Australian Bird & Bat Banding Scheme). The bats were on display in the Nocturnal House in an exhibit measuring about 5 x 1.5 m and was 2 m high.



PLATE 3 Blossom Bat at inflorescence of banana (I. Morris)

It was vegetated with small paperbarks (*Melaleuca* species) and many other live native shrubs, vines and grasses. Day light was simulated for 11 hours (21:00-10:00) using metal halide lights. These also provided the vegetation with a broad enough light spectrum to facilitate growth. From 10:00 to 21:00 "moon light" was simulated by 8 watt fluorescent lights with blue tinted gels. Public viewing was from 10:00 - 18:00.

The exhibit required relatively low maintenance. However, live vegetation needed to be fertilised on a regular basis, usually every 4-8 weeks, with an organic liquid fertiliser (e.g. "Maxicrop" Hortico). Trimming and training of the vines and pruning of the shrubs was necessary as the plants tended to grow up towards the light source giving an unnatural appearance. Grass tussocks and leaf litter had to be replenished on a regular basis. The bats did no damage to the exhibit, but their faeces were deposited on the glass regularly, and had to be cleaned off daily.

Food

As the common name implies, Northern Blossom-bats feed mainly on blossoms, collecting nectar and pollen with their long narrow tongues. Records of stomach

contents include some insects, but these are believed to be ingested accidentally (McKean 1983). Rate of passage is swift, with food passing completely through the gut in 30 minutes or less as in other Pteropodidae (Nelson 1989). In the wild, feeding usually commences at dusk. When feeding they either hang directly on the foliage, or hover near the blossoms just long enough to probe with their long thin tongues (Thomson 1991).

At the Territory Wildlife Park the provided food consisted of an artificial nectar mix, used by Taronga Zoo, Sydney (Woodside) for Queensland Blossom-bats *Syconycteris australis*. This consisted of a blend of 2 small bananas plus apple juice to make up 500 ml. To this mix was added 15 tablespoons of raw sugar (CSR), 6 tablespoons of High Protein Baby Cereal (Heinz) and 6 tablespoons of Infasoy (Wyeth Pharmaceuticals). When the above ingredients were well-blended, an equal volume of water was added. Daily rations were packaged separately in clip-seal bags and frozen. Approximately 20 ml was provided in each nectar feeder (Birdland UK), using one feeder per bat, plus one extra. The feeders were placed in a manner so that no one individual could monopolise the feeding area. This helped to ensure that young bats learning to feed were not harassed. Some feeders were hung in view of the public to give them the opportunity to observe the bats feeding at close quarters; their tongues can be seen lapping up the mix. The bats were fed at about 09:00 hours each morning after feeders from the previous day were removed.

The diet was supplemented occasionally with flowering branches of local plants; including species of *Melaleuca*, *Grevillea*, and *Eucalyptus*, availability and time permitting. Locally, these bats have been observed feeding on the flowers of exotic plants, such as bananas (I. Morris, pers. comm.). A nectar feeder of water was also supplied in the exhibit although the bats were seldom observed drinking from this feeder. Once the feeders with nectar were placed in the exhibit in the morning, the exhibit was sprayed with water, to help maintain the humidity. At this time, the bats were observed licking water droplets from foliage.

Reproduction

Breeding behaviour of the Northern Blossom-bat has not been described. It was known that births occur in the dry season, during August and September, from information from dissections of a few females (McKean 1983). However, recent observations suggest that they may well be polyoestrous. Births occur all year round in New Guinea (McKean 1983), and captive births at the Wildlife Park have occurred in February, March, April, October and December (Webber pers. obs.). When trapped, adult males showed marked variation in scrotal development, and the development of a V-shaped gland on the chest. This sternal gland is absent in females and juvenile males. The males produced a pungent and musky odour which is thought to originate from this gland.

Of the seven Blossom-bats displayed in the Nocturnal House, three (1 male: #683; 2 female :#686, #688) were adults when caught in the wild (the remaining four were

first generation captive bred). At capture, one female (#686) had quite large nipples indicating that she had most probably bred and suckled young previously, while the other female (#688) was thought to be sub-adult as nipples were not enlarged. The latter female was thought to be pregnant at time of capture, but no birth occurred. Attempts at mating were observed on several occasions. Each time the female was hanging and the male landed as close as possible to her, approached upside-down, and mounted her quickly. Copulation was swift, within about 10-15 seconds. Subsequently the male flew off and groomed his penis after settling.

Both females produced young in captivity. Prior to parturition, the females switched from regular roost sites to ones much lower in the exhibit and regularly groomed and licked the lower abdomen. After they had given birth the female usually returned to her previously preferred roost site. Female #686 gave birth to three males, one on each of the 30 April 1990, 11 December 1990 and 25 March 1991; #688 to one female on 21 October 1990. New born young had a fine covering of hair on their head and back; their bellies were bare, and muzzle short relative to adults. The eyes were closed and the ears were down flat against the head. The lateral margins of the outer ear were quite darkly pigmented, fading with maturation. They were almost always suckling on the mother's teat. Keepers observed juveniles hanging by themselves at 6-10 days for a short period. A hovering behaviour was observed in females with young prior to the young learning to fly. The dam hovered just out of reach of the young bat while the latter was hanging. This was observed in young between 11-30 days old.

Captive young could fly quite well by 40 days, but hung on the dam whilst at roost as long as possible. One six-month old male still hung on his dam on a regular basis. One female had her previous offspring hang on her from time to time throughout her pregnancy. Both the new born bat and this sub-adult were observed hanging from the dam simultaneously. At the time of writing, only one of the captive bred offspring has begun to show any sign of sexual maturation. At approximately 210 days old, the male born on 30 April 1990 started showing development of a sternal gland, followed by very slight scrotal development. It is quite possible that this development could be influenced by having to share the enclosure with several adults.

Vocalisation was not heard as frequently as in other captive Pteropids, possibly because of their small size or more solitary nature. Vocalisation usually occurs during fighting and in the more cantankerous individuals during handling. Young, separated from their dam, use a distinctive call apparently in distress which evokes an immediate response in the female both vocally and physically. She will call and try to reach the young bat. Independent sub-adult bats have been heard to give the juvenile distress call if harassed.

Discussion

The captive care, maintenance and breeding of the Northern Blossom-bat has been relatively uncomplicated. Four fatalities have occurred - two of these shortly after

capture, and the loss of a female and her newborn young a day after the birth. The causes of these deaths are uncertain. Stress would probably have been a major factor in the newly-caught specimens. Captive Queensland Blossom-bats have experienced a number of postpartum problems and resulting deaths (J. Webber, pers. obs.). To date no illness in the bats, or any problems with either endoparasites or ectoparasites have been observed. The only injuries have been minor ones associated with the forearm alloy bands. Once the bands were removed the injuries healed quickly.

The scope for further captive study of this species is large. Further observations of this group will provide data on age of sexual maturity, age of weaning and more comprehensive data on growth rates and maturation. That the species occurs naturally within the Park is an advantage and will enable collection of data on the wild population in the future.

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The Establishment of Eucalypt Seedlings in Tropical Savanna Forest

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Introduction

In wet temperate eucalypt forests, seed is released after occasional hot wild fires and seedlings germinate *en masse* in the ash bed (Mount 1969; Ashton 1976). This provides a cohort of single-aged trees that replace adult trees killed by fire. In tropical eucalypt forest, the ground layer permanently contains a mass of woody sprouts (Fensham & Bowman 1992) less than 1 m tall that are attached to lignotubers, rhizomes or root suckers (Lacey & Whelan 1976; Dunlop & Webb 1991). Germinant seedlings are a rare occurrence in most stands of tropical eucalypt forest despite annual fires (Lacey 1974; C. Dunlop, B. Wilson, pers. comm.; pers. obs.). Furthermore, seed fall of monsoon savanna eucalypts is not triggered by fire, but occurs upon fruit ripening (Dunlop & Webb 1991). These facts suggest that seedling establishment in the monsoon tropics does not conform to the model for temperate Australia.

In a study on Melville Island, Fensham & Bowman (1992) did not find any eucalypt saplings with small lignotubers, suggesting that tree regeneration does not occur from seedlings. Tree regeneration occurs when woody sprouts, with well developed underground parts, switch from a suppressed state to a sapling with relatively more continuous vertical growth. Most woody sprouts will never be trees and eventually become moribund and die. Seedlings must occasionally be recruited into the pool of woody sprouts if forest structure is to be maintained. There have been no documented studies of seedling establishment in the tropical savanna environment. This paper documents the fate of a sward of naturally occurring eucalypt seedlings for four years after germination.

Lacey (1974) suggests that a fire free period is necessary for the establishment of *Eucalyptus porrecta* seedlings in the eucalypt forest of Melville Island. This suggests that seedlings are tolerant of their own litter and the present study includes a field experiment designed to examine the allelopathic effect of eucalypt litter on seedling survival.

Methods

In the early wet season of 1987/88, a sward of *Eucalyptus miniata* and *E. tetrodonta* seedlings was located 6 km NE of Paru on Melville Island. The status of the

seedlings could be assured because cotyledonary leaves were evident on most individuals. At this time, a grid comprising 24 contiguous 2 x 2 m sub-plots was marked using steel pickets (Fig. 1). Most of the sward outside the grid comprised seedlings at lower densities than within the grid, and the total sward was contained within the area represented in Figure 1. Over each sub-plot a square frame defining a smaller scale grid comprising one hundred 20 x 20 cm cells allowed the mapping

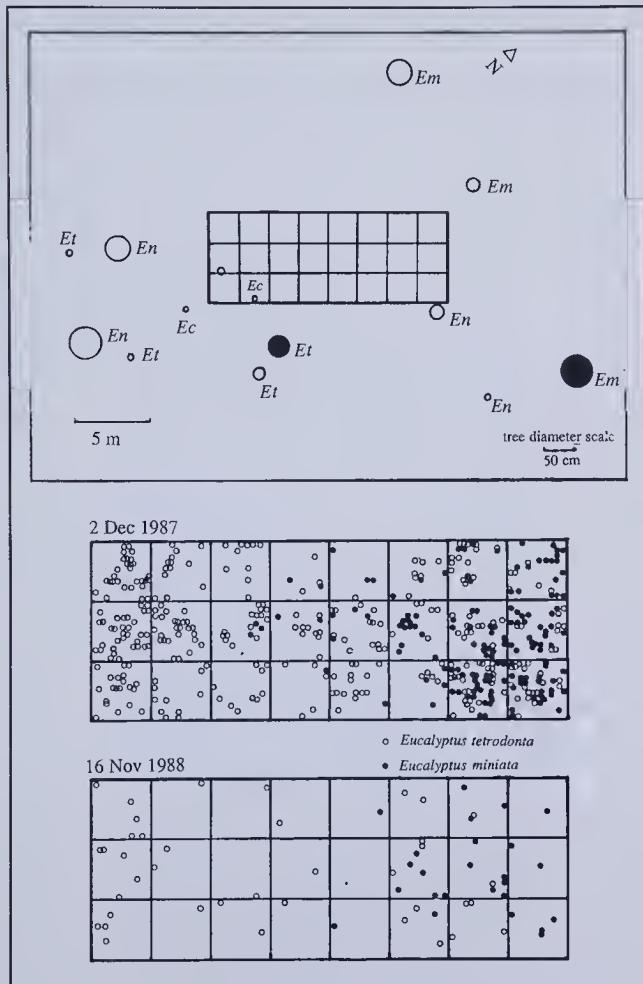


FIGURE 1 Plan of surrounding trees and germinant seedlings across the study plot at the initial and final sampling time. The mother trees of the seedlings are blacked out. *Ec*, *Eucalyptus confertiflora*; *Em*, *E. miniata*; *En*, *E. nesophila*; *Et*, *E. tetrodonta*.

of each seedling. The position and species of seedlings was noted on 2 December 1987; 7 March, 5 May, 12 June, and 16 November, 1988; and 5 January 1992. The projective foliage cover of all woody sprouts was mapped for the study grid. The diameter at breast height, height, crown radii, species and position of surrounding mature trees were noted. The plot was burnt on 30 July 1988 (mid-dry season) by a fire that incinerated all ground vegetation but left tree crowns unscorched. The plot was adjacent to a road and its ready accessibility probably assured it was burnt in most dry seasons of the recent past (Braithwaite & Estbergs 1985; Press 1988).

Twenty naturally occurring seedlings each of *E. miniata* and *E. tetrodonta* were mapped adjacent to the seedling plots. Eucalypt litter was collected in the late wet season (7 March 1988) from an unburnt eucalypt forest dominated by *E. tetrodonta* and *E. miniata* near Darwin. The forty mapped seedlings were mulched with this litter to a depth of 5 cm and radius of about 25 cm. Care was taken to ensure seedlings were not smothered by leaf litter. A further 20 individuals of each species interspersed throughout the mulched individuals were left unmulched to serve as a control, and the height and number of leaves of all plants in the experiment were measured. The seedlings were remeasured after two months and their heights and number of leaves compared between mulched and control treatments using Mann-Whitney U-tests. Mortality was compared using the Chi-square test.

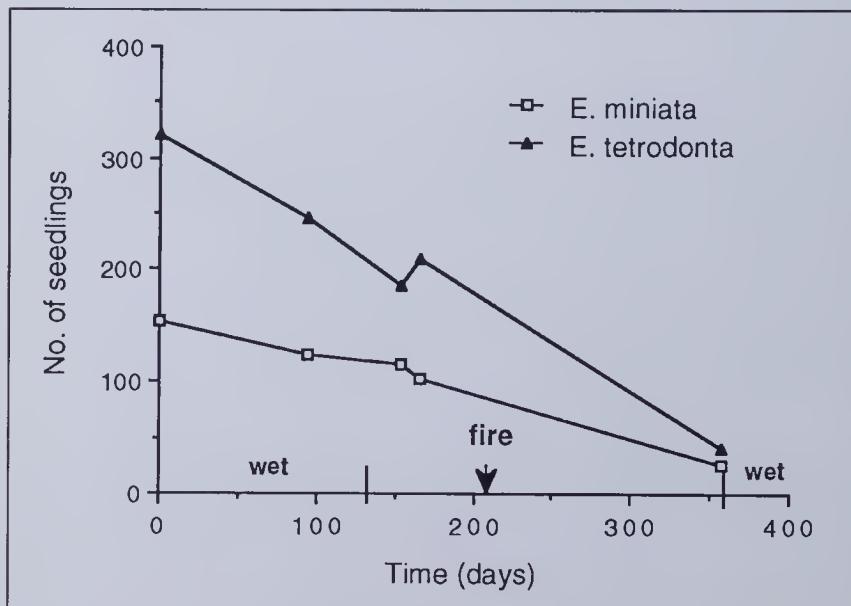


FIGURE 2 Number of seedlings within the study grid (96 m²) for the first year after germination.

In 1992, the lignotubers of 4 year old seedlings were excavated, measured and an estimate of their size provided by the lignotuber area index (cm^2). This was calculated as the area of the minimum rectangle that could enclose their area (Fensham & Bowman 1992).

Results

Seedling Density and Survival

The *E. miniatia* and *E. tetrodonta* parent trees (Fig. 1) were obvious because of the abundance of mature fruits under their canopies and the absence of fertile material on other trees in the vicinity. Their crown radii were approximately 6 and 4 m, and their heights 15 and 12 m respectively. It appears that seed can disperse at least three crown widths and 1.5 times the height of the parent tree.

New seedlings appear during the course of this study, but the mapping procedure was not precise enough for this recruitment to be quantified. Recruitment of new individuals accounts for the increased numbers of *E. tetrodonta* seedlings in the interval between the third and fourth samples (Fig. 2). This suggests that some seed remains viable after several months dormancy. A rudimentary lignotuber evident



PLATE 4 One year old *Eucalyptus miniatia* seedlings. Note the ligno-tuberous swellings and deep tap roots.

on seedlings excavated in April 1998 (Plate 4) allowed some seedlings to survive fire in the first dry season after germination.

There was no apparent preferential survival of seedlings in areas of the grid where the projective canopy cover of woody sprouts was relatively low (*E. tetrodonta*: $r = 0.023$, $p > 0.05$; and *E. miniatia*: $r = 0.296$, $p > 0.05$). There were only seven *E. miniatia* and nine *E. tetrodonta* survivors in December 1991 four years after germination. The mean lignotuber area index for the seedlings excavated in December 1991 was 0.90 cm^2 ($s.e. = 0.43$) for *E. miniatia* and 1.42 cm^2 ($s.e. = 0.41$) for *E. tetrodonta*. A selection of these excavated seedlings are depicted in Plates 5 and 6.



FIGURE 5 Four-year old *Eucalyptus miniatia* seedlings.

Effect of Litter

During the 2 months between the initial and final seedling measurements of the leave litter experiment, 213 mm of rain fell at Nguiu (10 km distant). This rainfall should have ensured that litter leachates were well washed through the seedling root zone. There was no significant difference in the initial and final heights or number of leaves between mulched and unmulched *E. miniatia* and *E. tetrodonta* seedlings ($p > 0.05$ in all cases). There was also no significant difference in mortality for *E. tetrodonta* (control - 15%; litter - 10%) or *E. miniatia* (control - 20%; litter - 25%) ($p > 0.05$).

Discussion

The survivorship of young seedlings is difficult to determine in this study because of some seedling recruitment after the initial germination event. However, the

maximum survivorship of young seedlings did not seem to be associated with low levels of woody sprout competition.

One year old seedlings of *E. miniatia* and *E. tetrodonta* rapidly develop a lignotuber and a deep root system (Plate 4). These allow survival of some individuals through the inevitable fire and drought of the oncoming dry season. The underground parts of nine month old tree seedlings endured the heat of a dry season fire and regenerated new stems. The perennating organs and deep root systems allows for the rapid replacement of above ground biomass.

The evidence from this study suggests that litter leachates do not contribute to seedling mortality in situations where litter has accumulated, which is consistent with observation of Dunlop *et al.* (1975) of *E. tetrodonta* in long unburnt forest on Elcho Island.

Fensham & Bowman (1992) record woody sprouts with lignotuber area indices up to 900 cm² for *E. miniatia* and up to 3000 cm² for *E. nesophila*. Lacey (1974) also draws attention to the large size of underground organs in the tropical eucalypt forest. The fact that lignotubers had only attained a range of lignotuber area indices between 0.11 and 4.16 cm² after four years growth (Plates 5 and 6) suggests that woody sprouts with relatively large lignotubers are of considerable antiquity. If woody sprouts survive in the ground layer for extremely long periods of time, spatially and temporally sporadic seedling recruitment such as reported in this study could maintain existing densities of woody sprouts.



PLATE 6 Four-year old *Eucalyptus tetrodonta* seedlings.

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SHORT NOTES

The Yellow-bellied Sea Snake *Pelamis platurus* in the Northern Territory

Of the fifty or more sea snake species that are found throughout the tropical waters of the Indian and Pacific Oceans, the Yellow-Bellied Sea Snake *Pelamis platurus* has the widest distribution. The pelagic existence of this species is in contrast with the more inshore and bottom-dwelling habits of the other species of sea snakes and sea kraits. The Yellow-Bellied Sea Snake is found from the Indian Ocean shores of southern Africa, through the tropical waters of South East Asia to the Pacific Ocean shores of Central America (Cogger 1975). Ocean currents carry specimens into the temperate waters of New Zealand (McCann 1966) and Tasmania (Cogger 1975). Along the south-east and south-west coasts (28° S to 33° S) of Australia the species is commonly encountered on beaches where it is washed after storms. As many of these specimens are taken to museums for identification, the Yellow-Bellied Sea Snake has been labelled as Australia's most common sea snake species (Krefft 1869; Kinghorn 1956). In contrast with the prevalence of this species on southern shores, it is rarely collected in Northern Territory waters.

In 1819, King described a specimen near Lacrosse Island near the present Northern Territory and Western Australian border. The snake was "three feet long; its back was black and belly yellow and the tail striped black and white." (King 1827, vol 1: 288). The conspicuous markings of the species ensured its inclusion in naturalist's notes. In September 1856, Thomas Baines sketched and painted a Yellow-Bellied Sea Snake which was caught by a crew member of the "Messenger" when off the coast of Flores, Indonesia. It was pickled in a bottle of rum, and described as "of rather venomous appearance" (Braddon 1986). Museum records reveal a steady rate of collection of the species since 1904 from several localities in the Arafura and Timor Seas and from the coast of northern Australia in general (Table 1). This reflects collecting effort from this largely uninhabited coastline rather than abundance of this species.

In the South-east Asian region, the Yellow Bellied Sea Snake is known from a number of localities. Specimens are reported from Flores and Ambon (de Rooij 1917), and single records from Cocos-Keeling Island (Gibson-Hill 1950), Christmas Island (Table 1), and Ashmore Reef (Minton & Heatwole 1975). Several specimens have been collected from the Gulf of Carpentaria (Heatwole 1975; Covacevich & Couper 1991; Table 1). A single specimen of this species was collected from the Torres Strait region during the Soviet sea snake surveys and was thought to indicate that the species was carried into the Arafura and Timor Seas by currents from the Coral Sea (Shuntov 1972).

In November 1988, I collected a freshly beach-washed, dead, male specimen (Plate 7) from Dundee Beach, Fog Bay ($12^{\circ}41'S$, $130^{\circ}21'E$). Its snout-vent length was 578

mm, tail length 82 mm, and weight, 127 g. The animal was in good condition with no sign of commensal organisms which might indicate a prolonged period of ill health. The scale rows at the mid body numbered 49 with 321 ventral scales and 47 subcaudals. In size, colour and sculation this specimen is similar to other Australian specimens. Like many of the specimens in Australian museums, this individual had been stranded by a combination of an ebbing tide and onshore winds.



PLATE 7 The male Yellow-Bellied Sea Snake washed ashore at Dundee Beach, Fog Bay in November 1988 (M. Guinea)

As reproductively mature and immature specimens have been collected off the New South Wales and Western Australian coasts, it has been assumed that these waters support viable populations of the Yellow-Bellied Sea Snake (Cogger 1975). The population status of this species in Northern Territory waters remains unclear. The small snout-vent lengths of R.2081 (154 mm) and R.13210 (310 mm) (Table 1) are indicative of immaturity, and suggest local breeding. Are Northern Territory specimens simply waifs that have been blown from their normal range as assumed by Shunsov (1972), or are they part of a geographically discrete yet seldom encountered breeding population? More specimens are required and any beach washed animals presented to the Northern Territory Museum could significantly improve our knowledge of this species.

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TABLE 1 Museum specimens of the Yellow-Bellied Sea Snake *Pelamis platurus* that were collected from the Arafura and Timor Seas, Gulf of Carpentaria and the North Australian province of the Indian Ocean. AM, Australian Museum; WAM, Western Australian Museum; and NTM, Northern Territory Museum.

Museum	Specimen No.	Locality	Year of collection
AM	R.3390	Darwin Harbour N.T.	1902
AM	R.14426	Arafura Sea	1949
AM	R.44551	Gulf of Carpentaria	1961
AM	R.44553	Gulf of Carpentaria	1961
AM	R.21243	Kurumba, Gulf of Carpentaria	1964
AM	R.42005	Ashmore Reef, Timor Sea	1972
AM	R.39018	Ashmore Reef, Timor Sea	1973
AM	R.37362	Thursday Island	1972
WAM	39747	Christmas Island, Indian Ocean	1969
WAM	46134	Dillon Shoals, Timor Sea	1974
NTM	R.17799	York Sound, W.A.	1975
NTM	R.2081	Weipa, Gulf of Carpentaria	1975
NTM	R.13210	Cape Wessel, Arafura Sea	1985

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Further Records of the Carpentarian Rock-rat *Zyzomys palatalis* from the Gulf Region of the Northern Territory

In a recent review of the rat genus *Zyzomys*, Kitchener (1989) described a new species, *Z. palatalis*, from the Gulf region of the Northern Territory. This description was based on the only three specimens known (one adult and two juveniles), collected in 1987 and 1988 from sandstone monsoon rainforest vegetation at Echo Gorge ($17^{\circ}12'S$, $137^{\circ}41'E$) in Wollogorang Station, during a detailed wildlife survey of the NT Gulf district by the Conservation Commission of the Northern Territory. To date these are the only published records of this species, and concern about its conservation status has been expressed (e.g. Australasian Rodent Specialist Group 1992 listed the species as of Indeterminate status), especially as a hot fire destroyed much of the habitat in Echo Gorge after the initial collecting (K. Johnson pers. comm.).

During 1990 we surveyed mammals in 50 patches of monsoon rainforests across the NT (Menkhorst & Woinarski 1992), including several patches in the Gulf region. On 3-6 June 1990 we trapped a total of 14 individuals of *Z. palatalis* at two monsoon rainforest patches in a sandstone gorge at the headwaters of McDermotts Creek ($17^{\circ}25'S$, $137^{\circ}48'E$), about 30 km SSE of the type locality. Two specimens were collected, and their identity confirmed by D. Kitchener (WA Museum).

Habitat at our capture sites was dry rainforest thicket (including the trees and shrubs *Gyrocarpus americanus*, *Celtis philippinensis*, *Pouteria sericea*, *Terminalia volucris*, *Diospyros humilis*, *Ficus leucoxantha*, *Ficus opposita*, *Antidesma parvifolium*, *Brenya cernua*, *Croton habrophyllus*, *Exocarpos latifolius* and *Flueggea virosa*, and the vine *Opilia amentacea*) growing around escarpment, similar to the habitat given for the type locality. Canopy height was 5-6 m, and canopy cover, 50-70%. Rock cover was greater than 95%, and there was less than 5% cover of tussock grasses. The two patches were 1 and 6 ha in area, and separated by about 500 m. We also trapped simultaneously in surrounding savanna woodland (dominated by *Eucalyptus brevifolia*), open forest (dominated by *E. papuana*), and tall (15 m) rainforest on a spring c.1 km downstream of the thickets, without catching *Z. palatalis*. The common Rock-rat *Zyzomys argurus* was captured in these three habitats, and also in one of the two thickets.

Without further survey work in the Gulf region, it is impossible to define the conservation status of *Z. palatalis*. We currently know too little of its distribution, abundance and relationship to fire or grazing. As with its close relatives *Z. woodwardi* and *Z. maini*, *Z. palatalis* would appear to be associated with monsoon rainforests of sandstone escarpments, which provide the fleshy fruits and large seeds on which this group depends (Begg & Dunlop 1985). Many of these habitats

are being degraded in the Gulf region by changed fire regimes and the effects of grazing by cattle and feral stock (Holmes 1990; Russell-Smith & Bowman 1992).

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